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# INFLUENCE OF ASE ON THE PERFORMANCE OF EDFA & YDFL IN FIBER AMPLIFIERS

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## ABSTRACT

Fiber amplifiers are replacing conventional bulk optical devices in a variety of applications. Ytterbium-doped fibers are of particular interest in high power applications due to their numerous advantages arising from a simple electronic structure. The behavior of Ytterbium-doped fiber devices is however strongly influenced by the selection of absorption and emission wavelengths and other parameters. By careful theoretical analysis the performance of the fiber device can be optimized and to estimate the influence of amplified spontaneous emission, photo darkening and other such phenomena. In the work, effect of ASE for EDFA and YDFL are investigated. Due to the effect of ASE the gain of fiber amplifier is reduced. The effect of ASE is more in EDFA than in YDFL. In the simulation result it is found that gain is less in case of EDFA than YDFL. So YDFL is preferred due to high peak power, large pulse energy and low ASE. The specific properties and characteristics of Ytterbium-doped fibers which make them highly attractive for high power fiber applications.

**KEYWORDS:** Erbium Doped Fiber Amplifier, Ytterbium Doped Fiber Amplifier, ASE

## INTRODUCTION

Erbium doped fiber amplifiers can be used for amplifying high speed digital signal which has low insertion loss, ease of achieving travelling wave amplification and immunity to crosstalk in wavelength division multiplexed systems. The noise figure is very low for a Erbium doped fiber amplifier. In case of Yb-doped fiber considered ring and linear cavity Yb-dopped fiber. In case of YDFA, the Q-switched laser pulses are very useful in applications of industrial manufacturing, laser ranging because of their unique characteristics in high peak power, large pulse energy and obtaining narrow line width. So YDFL is better than other fiber lasers. But in case of EDFA three types of noise is generated at the receiver (i) signal to spontaneous (ii) spontaneous to spontaneous and circuit noise.

### Noise and Nonlinear Effects

Noise is any deviation from the original output signal which is associated with random processes. An amplifier amplifies the input seed along with produces excess unwanted noise. In an optical amplifier, the noise usually occurs in the form of spontaneous emission. By the quantum effects in the gain medium, spontaneous emission is created and is typically non-directional. However, in a fiber-based gain medium, amplified spontaneous emission (ASE) is seen due to the large aspect ratio and wave guidance which can cause a highly directional amplification. ASE is the most significant noise in optical amplifiers that limits the gain of the device. The long interaction lengths in fibers combined with the light confinement in a relatively small core area results in high optical intensities inside the core which leads to various

nonlinear effects in the fiber such as self phase modulation, cross-phase modulation, four-wave mixing, Kerr-effect, Raman and Brillouin scattering. These nonlinear effects can be useful phenomena for broadening of light in different applications such as super continuum generation. However, in most of the applications like high power amplifier and laser, these nonlinearities can cause fiber damage and can limit the performance of the device. So optimum design of fibers is essential to combat the noise and nonlinear effects. Besides the fiber designs, these effects can influence the nature of the optical gain medium. For instance, the spontaneous emission factor increases with the decrease in number of energy levels involved in the amplification process.

**Optical Amplifier**

Optical amplifier, as their names imply, amplify light signals solely in the optical domain without the need for optical to electronic conversion. An optical amplifier operates using the same physical mechanisms as a laser. Only difference for optical amplifier is not having any feedback of the signal as lasers do have (EDFA is a kind of laser without feedback).

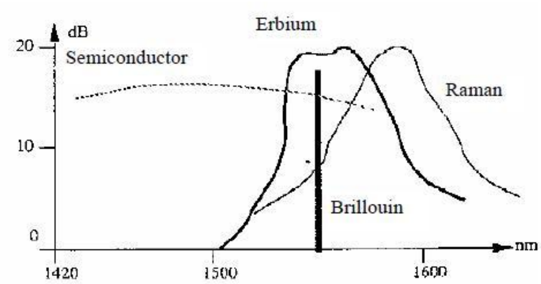


**Figure 1: Semiconductor, Erbium, Raman & Brillouin Amplifier Gain Spectra**

The two main approaches to optical amplification to date have concentrated on semiconductor optical amplifiers which utilize stimulated emission from injected carriers and fiber amplifiers in which gain is provided either stimulated Raman or Brillouin scattering. Both amplifier types i.e semiconductor and fibers pecifically rare earth and Raman have the ability to provide high gain over wide spectral bandwidths, making them eminently suitable for optical fiber system applications.

Erbium fiber amplifier operates only in the 1550nm window while semiconductor optical amplifier covers both the 1300nm and 1550 nm transparent windows.

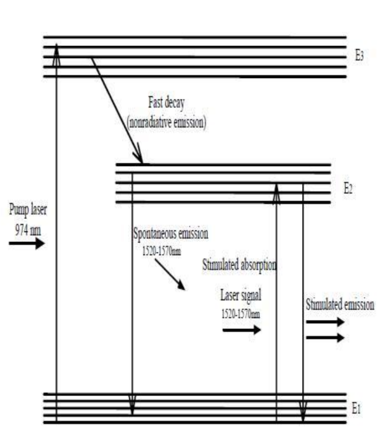


**Figure 2: Energy Level of Er3+ Ions in EDFA**

An EDFA is an optical fiber of which the core is doped with the rare earth element Erbium. By exciting the Erbium ions to higher energy levels, we can achieve amplification of signals at wavelengths interesting for optical communication i.e around 1550nm. The energy levels are not sharp, which leads to a relatively large gain bandwidth. In order to excite the Er3+ions, we send a beam of light, which we call the pump, into the fiber. If the pump is at wavelength 980nm, Er3 will rise from the ground state L1 to the higher L3 as illustrated in Figure. However, the ions will rapidly decay to energy level L2 without producing photons. The lifetime in L3 is approximately 1µs. Pumping with 1480 nm light will excite the ions directly to state L2. Relaxation from L2 to L1 will occur after approximately 10ms, producing photons in the wavelength band 1520-1570nm. This is called spontaneous emission.

Erbium Doped Fiber Amplifier operation is based on stimulated emission mechanism. When erbium ions are incorporated into silica fiber, each of their energy levels splits into a number of closely related levels. The information signal stimulates transition of the excited ions to the lower energy band. These transitions result in the radiation of photons with same energy or same wave length as the input signal. The most important energy levels of Erbium ions incorporated into a silica fiber is shown in Figure 2. Since an EDFA has a relatively wide gain bandwidth, it can amplify many wavelengths simultaneously.

**Generation of ASE in case of Erbium Doped Fiber Laser**

The gain and noise of the EDFA can be measured by using the experiment setup which is shown in the figure. In which the pumping light is given from the F-centre laser tuned to 1493nm is combined with the optical signal from an external cavity semiconductor diode laser using polarizing beam splitter.

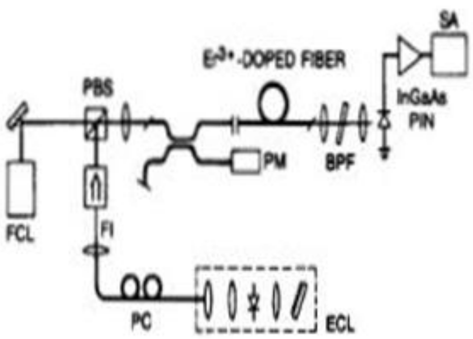


**Figure 3: Experiment Setup FCL-F-Center Laser, PBS-Polarizing Beam Splitter, I-Faraday Optical Isolator, PC-Polarization Controller; ECL-External Cavity Laser; PM-Optical Power Meter; BPF-Band Pass Filter; SA-RF Spectrum Analyser**

Light power launched into the amplifier was monitored using a 1 percent fiber coupler tap; the straight through port of the coupler was butt-spliced to the EDFA. The amplifier output was filtered with a band pass filter having a bandwidth of 2.6nm centered at the signal wavelength. The amplified signals are detected with a receiver consisting of a p-i-n photodiode followed by a 50Ω amplifier. The receiver noise was primarily

- Signal-spontaneous(s-sp) beat noise
- Spontaneous-spontaneous (sp-sp) beat noise
- Receiver circuit

This beat noise depends on the pump power launched into the fiber amplifier, since it affected the amplifier gain and amplified spontaneous emission (ASE). The beat noise and gain versus the launched pump power at constant input power signal.

**Drawback of Erbium Doped Fiber Amplifier**

- Relatively large devices (km lengths of fiber)–not easily integrated with other devices.
- Non uniform gain spectrum for which there is imbalance at the receiver side.
- ASE-amplified spontaneous emission. There is always some output even with signal input due to some excitation of ions in the fiber–spontaneous noise. Pump laser necessary.
- Need to use a gain equalizer for multistage amplification.
- Dropping channels can give rise to errors in surviving channels.

**Ytterbium Doped Fiber Lasers**

The outer cladding makes the double clad fibers distinct from regular fibers. A typical double clad fiber is can only work with a single-mode output with the core and the inner cladding working in a highly multimode regime for the pump power. The inner cladding shape is normally non-circular to make more pump power to enter the fiber core; if the inner cladding is circular then few pump modes will cross the doped core and the pump efficiency will be low. However, the core can be offset from the centre to improve the efficiency.

**How ASE is Generated in Case of YDFL**

Ytterbium doped fiber Laser is better than other doped fiber laser because of their unique characteristics. Application such as nonlinear frequency conversion, range finding & remote sensing require short, high energy pulses. For these applications Q-Switched fiber lasers are now emerging as a leading contender due to their simplicity compactness. Switched laser pulses are very useful in applications of industrial manufacturing laser ranging, medicine & nonlinear optics because of their unique characteristics in high peak power, large pulse energy and easily obtaining narrow line width.

Basically we are considering Q-Switched YDFA with ring and linear cavity. Hear the ASE reduce the gain and by using ASE filter we can enhance the gain. The influence of ASE on the output characteristics of Q-Switched fiber laser as threshold, pulse duration and peak power. By considering the schematic configuration of the ring & linear cavity Q-switched YDFA we investigate the influence of ASE.

The two lasers have the same specifications with the absorption of 528dB/m at 976nm and a length of 1.8Ma 975nm laser diode (LD) with the maximum output power of 300mW was used as the pump. Through wavelength division multiplexing coupler, the pump light was launched into the YDF which has insertion loss of 0.4dB. The acousto-optic modulator (AOM) is used which has insertion loss of 1.5dB and the extinction radio more than 30dB in its operation region of 1064±5nm.

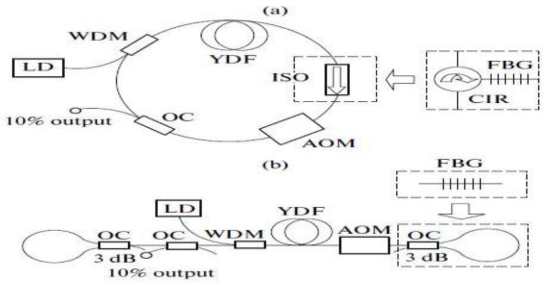


**Figure 4: Configuration of Q-Switched YDFL**

The modulation frequency and the rise time of the AOM may be adjusted to any values between 5 and 80 kHz and 200 ns. In case of ring cavity laser an optical Isolator is used which has insertion loss of 1.5dB was for unidirectional transmissions. In case of linear cavity two fiber loop mirror based on 3dB optical coupler used 10% port of a 10:90 OC was used for the laser output which was then measured with an optical spectrum analyzer (OSA) and fast photo detector followed by a 600MHz oscilloscope. For considering the output properties of the ring cavity Q-Switched YDFL, the modulation frequency and rise time of the AOM were fixed at 5KHz and 10ns. When pumping is 50mW in which t=0 stands for the moment when the AOM starts to open, the pulse buildup time is about 900ns and the pulse has slight amplitude fluctuations.

## RESULTS AND SIMULATIONS

Figure 5 shows gain plotted versus wavelength for a constant pump power. The amplifier peak gain at signal wave length 1560nm is 10.5dB. For shorter wavelength with lower gain remains constant.

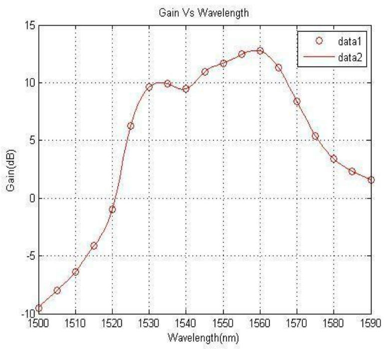


**Figure 5: Gain versus Wavelength for Different Input Signals**

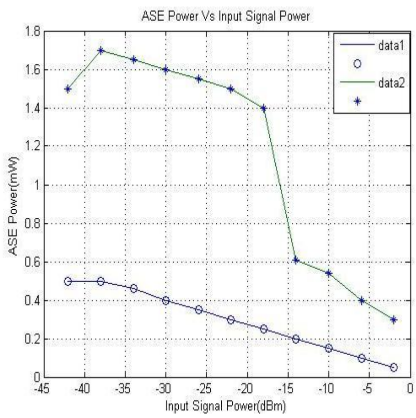


**Figure 6: Input Signal Power versus ASE Power for EDFA**

Figure 7 shows the average output power of the Q-switched ring cavity laser with the filter as function of the pump power. It can be seen that the threshold is about 55mW,much lower than that without the ASE filter, which is about 220mW,indicating that the laser threshold has been decreased by inserting the filter and the output power of the pulse increases almost linearly with the pump beyond the threshold.

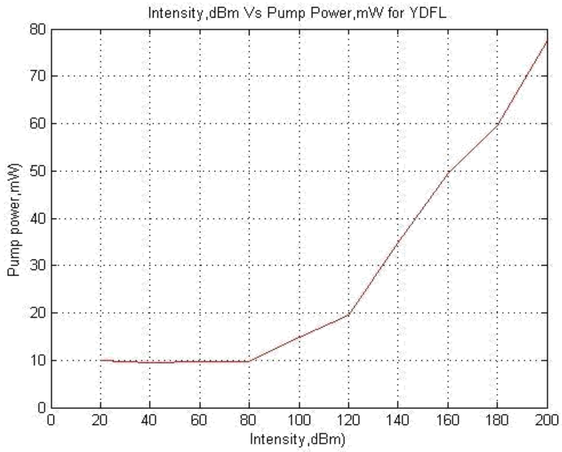


**Figure 7: Intensity versus Pump Power for Ytterbium Doped Fiber Laser**

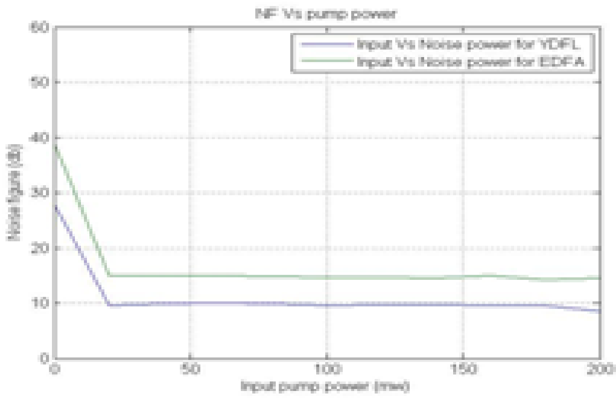


**Figure 8: Noise Figure versus Pump Power for EDFA & YDFL**

## CONCLUSIONS

Despite the disadvantages such as re-absorption losses and pronounced ASE, Ytterbium-doped fibers offer many advantages such as high power efficiency, low thermal effects and high gain bandwidth. These advantages make them especially attractive for high power and ultra-short pulse propagation applications. In this paper we presented the study of EDFL and YDFL and their applications with different parameters In the simulation result we found that due to the effect of ASE the power fluctuation, resulting in the multi peak structure, pulse buildup time decreases with increasing pump. So the output power is very low. In this simulation result we found that gain is more in case of YDFL than EDFA. By using ASE filter it can suppress the initial ASE. So as a result gain supplied by the YDFL can be greatly enhanced. Based on the study of Ytterbium-doped fibers and verification of the simulation tool, more complex fiber systems can further be designed.

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